Cryo-Etched Black Silicon for Use as Optical Black

NASA's Jet Propulsion Laboratory, Pasadena, California

Stray light reflected from the surface of imaging spectrometer components — in particular, the spectrometer slit — degrade the image quality. A technique has been developed for rapid, uniform, and cost-effective black silicon formation based on inductively coupled plasma (ICP) etching at cryogenic temperatures. Recent measurements show less than 1-percent total reflectance from 350–2,500 nm of doped black silicon formed in this way, making it an excellent option for texturing of component surfaces for reduction of stray light.

Oxygen combines with SF_6 + Si etch byproducts to form a passivation layer atop the Si when the etch is performed at cryogenic temperatures. Excess flow of oxygen results in micromasking and the formation of black silicon. The process is repeatable and reliable, and provides control over etch depth and sidewall profile. Density of the needles can be controlled to some extent.

Regions to be textured can be patterned lithographically. Adhesion is not an issue as the nanotips are part of the underlying substrate. This is in contrast to surface growth/deposition techniques such as carbon nanotubes (CNTs).

The black Si surface is compatible with wet processing, including processing with solvents, the textured surface is completely inorganic, and it does not outgas.

In radiometry applications, optical absorbers are often constructed using "gold black" or CNTs. This black silicon technology is an improvement for these types of applications.

This work was done by Karl Y. Yee, Victor E. White, Pantazis Mouroulis, and Michael L. Eastwood of Caltech for NASA's Jet Propulsion Laboratory. NPO-47883

Advanced CO_2 Removal and Reduction System

Lyndon B. Johnson Space Center, Houston, Texas

An advanced system for removing CO_2 and H_2O from cabin air, reducing the CO_2, and returning the resulting O_2 to the air is less massive than is a prior system that includes two assemblies — one for removal and one for reduction. Also, in this system, unlike in the prior system, there is no need to compress and temporarily store CO_2. In this present system, removal and reduction take place within a single assembly, wherein removal is effected by use of an alkali sorbent and reduction is effected using a supply of H_2 and Ru catalyst, by means of the Sabatier reaction, which is $CO_2 + 4H_2 \rightarrow CH_4 + O_2$. The assembly contains two fixed-bed reactors operating in alternation: At first, air is blown through the first bed, which absorbs CO_2 and H_2O. Once the first bed is saturated with CO_2 and H_2O, the flow of air is diverted through the second bed and the first bed is regenerated by supplying it with H_2 for the Sabatier reaction. Initially, the H_2 is heated to provide heat for the regeneration reaction, which is endothermic. In the later stages of regeneration, the Sabatier reaction, which is exothermic, supplies the heat for regeneration.

This work was done by Gokhan Alptekin, Margarita Dubovik, and Robert J. Copeland of TDA Research, Inc., for Johnson Space Center. For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. MSC-23480-1/4523-1

Correcting Thermal Deformations in an Active Composite Reflector

Composite actuators can be embedded into an easy-to-manufacture flat surface.

NASA's Jet Propulsion Laboratory, Pasadena, California

Large, high-precision composite reflectors for future space missions are costly to manufacture, and heavy. An active composite reflector capable of adjusting shape *in situ* to maintain required tolerances can be lighter and cheaper to manufacture.

An active composite reflector testbed was developed that uses an array of piezoelectric composite actuators embedded in the back face sheet of a 0.8-m reflector panel. Each individually addressable actuator can be commanded from –500 to +1,500 V, and the flatness of the panel can be controlled to tolerances of 100 nm. Measuring the surface flatness at this resolution required the use of a speckle holography interferometer system in the Precision Environmental Test Enclosure (PETE) at JPL.

The existing testbed combines the PETE for test environment stability, the speckle holography system for measuring out-of-plane deformations, the active panel including an array of individually addressable actuators, a FLIR thermal camera to measure thermal profiles across the reflector, and a heat source. Use of an array of flat piezoelectric actuators to correct thermal deformations is a promising new application for these actuators, as is the use of this actuator technology for surface flatness and wavefront control. An isogrid of these actuators is moving one step closer to a fully active face sheet, with the significant advantage of ease in manufacturing. No extensive rib structure or other actuation backing structure is required, as these actuators can be applied directly to an easy-to-manufacture flat surface.

Any mission with a surface flatness requirement for a panel or reflector structure could adopt this actuator array concept to create lighter structures and enable improved performance on orbit. The thermal environment on orbit tends to include variations in temperature during shadowing or changes in angle. Because of this, a purely passive system is not an effective way to maintain flatness at the scale of microns over several meters.

This technology is specifically referring to correcting thermal deformations of a large, flat structure to a specified tolerance. However, the underlying concept (an array of actuators on the back face of a panel for correcting the flatness of the front face) could be extended to many applications, including energy harvesting, changing the wavefront of an optical system, and correcting the flatness of an array of segmented deployable panels.

This work was done by Samuel C. Bradford and Gregory S. Agnes of Caltech, and William K. Wilkie of Langley Research Center for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). ***NPO-47755***